Preliminary

The Large Compressive Deformation of Wood in the Transverse Direction

—Difference of Deformation Pattern due to Species—

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Introduction

Recently, wood processing based on the transverse compression technique has attracted interest. In spite of its importance, little work has been reported so far on the basic mechanics of the compressive deformation process in the transverse direction. The present paper describes the relationship between the deformation pattern appearing in the wood cross section and the stress-strain diagrams for various species including both soft- and hardwoods. To clarify the cause of the characteristic deformation pattern due to species, we also attempted deformation analysis of cell wall using a P-version finite element method.

Materials and Methods

For 21 species including 4 softwoods and 17 hardwoods (Table 1) conditioned almost to the fiber saturation point, compression tests in the transverse direction were performed at room temperature, and their gross deformation patterns were observed simultaneously with an optical microscope. The size of specimen was 20 mm (R) by 20 mm (T) by 10 mm (L). On the basis of the cell arrangement in the cross section of Hinoki wood observed with a scanning electron microscope (SEM), compressive deformation pattern and the accompanying stress-strain relationships were calculated using P-version finite element method (Stress Check v.4.0, ESRD Inc.) under the condition that all the cell walls are elastically isotropic.

Results and Discussion

For all the species examined, the stress-strain relationships in the transverse direction were expressed in a uniform manner in terms of an empirical equation including three parameters, k, c and m[1,2] : the k was related

Table 1. Test species.

	Wood species	Specific gravity
Softwood	Sugi (*Cryptomeria japonica* D.)	0.38
	Hinoki (*Chamaecyparis obtusa* Endl.)	0.44
	Akamatsu (*Pinus densiflora* Sieb.)	0.52
	Agathis (*Agathis alba.*)	0.53
Diffuse-porous wood	Balsa (*Ochroma logopus* Sw.)	0.12
	Onigurumi (*Juglans ailanthifolia* Carr.)	0.43
	Honoki (*Magnolia obovata* Sieb.)	0.45
	Katsura (*Cercidiphyllum japonicum* Sieb.)	0.5
	Tochinoki (*Aescultu turbinate* Blume.)	0.52
	Kusunoki (*Cinnamomum camphor* Sieb.)	0.55
	Sakura (*Prunus sargenitii* Rehd.)	0.62
	Buna (*Fagus crenata* Blume)	0.65
	Urihadakaeda (*Acer rufinerve* Sieb.)	0.69
Radial-porous wood	Tsuburajii (*Castanopsis cuspidata* Schoottky)	0.52
	Akagashi (*Qurecus acuta* Thunb.)	0.87
Ring-porous wood	Kiri (*Paulownia tomentosa* Steud.)	0.3
	Harigiri (*Kalopanax septemlobus* Koidz.)	0.49
	Harunire (*Ukumus davidiana* Planch)	0.57
	Kuri (*Castanea crenata* Sieb.)	0.67
	Mizunara (*Quercus mongolica* Fish)	0.7
	Konara(*Q. serrata* Thunb.)	0.72

*[1] A part of this paper was presented at the 49th Annual Meeting of the Japan Wood Research Society in Tokyo, April, 1999.
*[2] Laboratory of Property Enhancement.

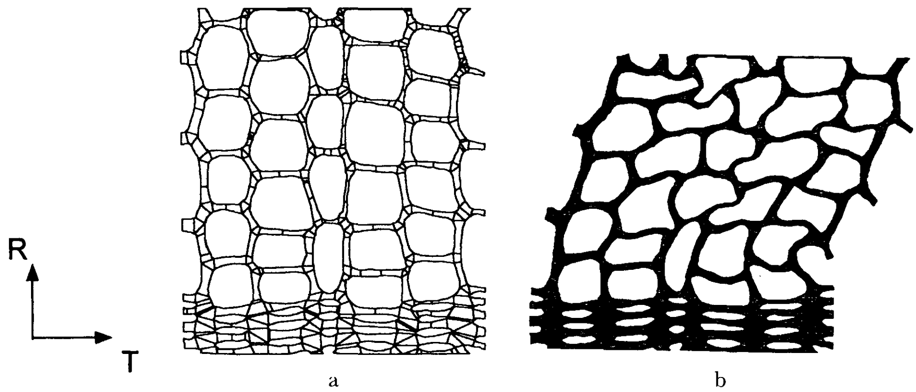

Fig. 1a. Cell arrangement of Hinoki model for calculation.
Fig. 1b. Result of *P*-version finite element analysis when compressed radially to a strain of 0.15.

to the Poisson's effect in the densification region, the *c* to the rising rate of the stress above the yield point, and m to the flatness of the stress-strain curve between the yield point and the densification point. Among these parameters, the m was unity for all the hardwoods, while it took more than 2 for almost all the softwoods irrespective of the direction of compression. On the other hand, for the diffuse-porous woods among the hardwoods, the *k* and m clearly depended on the specific gravity: the *k* values decreased, while *c* increased with increasing the specific gravity. Such difference in species seemed to be closely related to the deformation pattern in the transverse direction. For softwoods with $m=2$, a remarkable shear deformation occurred by compressive loading in both the *R* and *T* directions except for Agathis wood whose m value was unity. On the other hand, for the diffuse-porous woods, such deformation was not observed, but, the deformation typical of continuous material with homogeneous property was observed.

In an effort to further clarify the relationship between the deformation pattern and the cell arrangement in the transverse direction, we attempted a *P*-version finite element analysis[3] including a large deformation area for Hinoki model (Fig. 1a). The result in *R* direction was illustrated in Fig. 1b. When applying a compressive strain as large as 0.15 was applied, early wood portion largely leaned to the right side, showing shearing deformation as a whole. Such deformation was more apparent in the *T* direction. These calculations were in accord with the SEM observation of the compressed wood. We further learned that the calculated stress value increased linearly up to a strain of 0.02, and then leveled off, which corresponded to the observed stress-strain relationship.

References

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